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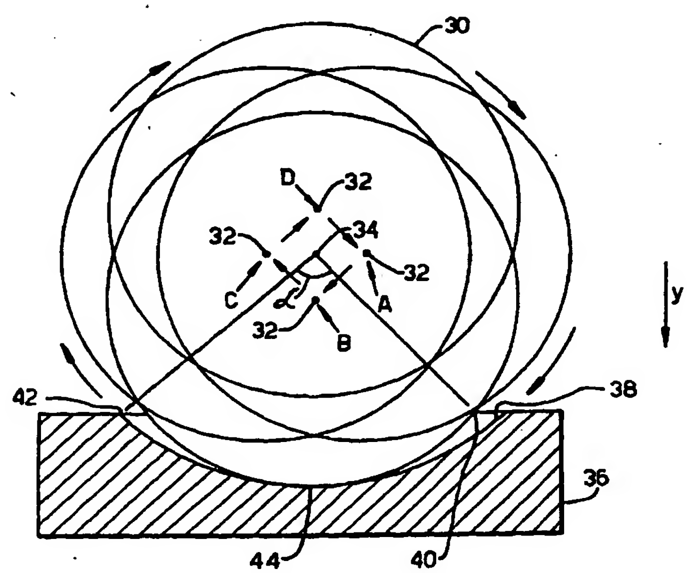

(57) Abstract

A method of abrasively removing material from a workpiece, the method comprising the steps of rotating an abrasive wheel about a first axis and orbiting the wheel about a second axis spaced from the first axis to contact said workpiece with a circumferential surface of the wheel to remove material therefrom.

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APPARATUS AND METHOD FOR ABRASIVELY REMOVING MATERIAL

The present invention relates to apparatus and a method for abrasively removing material from a workpiece. In particular, the present invention relates to apparatus and a method for sectioning a workpiece in which an abrasive wheel sections the workpiece by making a cut in the workpiece and progressively increasing the depth of the cut.

The term "wheel" as used herein is to be construed broadly to include any abrasive body of rotation. Thus the term ranges from a thin abrasive cutting or sectioning saw to a tool of significant axial length which may have a profiled periphery.

Such abrasive wheels are formed generally from sharp abrasive particles held in a resin. As the cutting edge of a fresh wheel is abraded, the resin is worn away to expose the sharp edges of the abrasive particles at the cutting edge. These sharp edges in time become blunted. However, with a sufficient shear force per unit area applied thereto by the material during sectioning, the blunted abrasive particles will eventually be forced out from their position in the wheel to allow the diameter of the wheel to be reduced so that further sharp abrasive particles are exposed at the cutting edge. Preferably, the abrasive particles should be retained within the wheel only until the cutting abrasive becomes blunted.

Figure 1 shows how the contact arc a of a wheel 10 rotating about axis 11 passing through the centre of the wheel with the material or workpiece 12 increases from a_1 to a_2 as the depth d of the cut increases from d_1 to d_2.

If the wheel 10 is advanced into the material 12 at a constant force F, the shear force F1 per unit area of wheel in contact with the material will decrease as more of the wheel contacts the material, i.e. the contact arc a increases.

This decrease in the shear force can give rise to a situation wherein the shear force F2 per unit area of wheel required to remove blunt abrasive particles from the cutting edge (in order to expose fresh abrasive particles) is not reached. This has the effect of blunting the wheel, with the likelihood that the wheel will induce structural damage within the material. Such a problem is particularly acute in the sectioning of circular blocks of material, in which the contact arc *a* increases rapidly during sectioning.

Therefore, it is desirable that the shear force F1 acting on the abrasive particles during sectioning, and, therefore, the contact arc *a*, remains approximately constant. Accordingly a constant "plunge" cutting action in which the contact arc *a*, and the cutting force, varies greatly during sectioning is undesirable.

One approach is to use a pulse action where the force F is interrupted whilst the wheel is in contact with the material and then fully reinstated. Such a pulse action is intended to produce a momentarily high shear force F1, thereby introducing fresh sharp abrasive particles to the cutting edge of the wheel. However, if wheel life is not to be sacrificed, it is essential that F2 is not greatly exceeded; it has been found that pulse action sectioning can reduce wheel life by as much as one half.

It is also desirable to maintain the contact arc *a* at a relatively low value, as the degree of residual damage induced in the sectioned faces of the material increases with the size of the contact arc *a*.

Figure 2 shows a schematic diagram of an abrasive wheel 14 traversing material, or workpiece, 16 of substantially rectangular cross-section during the sectioning thereof. The wheel rotates about an axis passing through the centre thereof and passes across the workpiece 16 to form a cut of substantially uniform depth in the material.

For this method to produce a uniform cutting arc no "feed" of the wheel, i.e. motion of the wheel to increase the depth of the cut, must take place during material removal. For the wheel to progress through the workpiece feed must take place whilst the wheel is not in contact with the workpiece. Therefore the stages of the motion of the wheel are an incremental feed followed by a traverse of the work to produce a cut of depth d, then another incremental feed followed by a traverse of the work to increase the depth of the cut to $2d$ and so on.

In other words, in order to maintain a constant contact arc a, the wheel must move across the material so that (i) the base 18 of the cut with depth d is substantially parallel to the base 20 of the cut of depth $2d$ and (ii) the increase in the depth of the cut is substantially constant.

With this action time is wasted during the cut as the traverse motion is suspended whilst the incremental feed takes place. If constant feed is introduced a uniform contact arc a cannot be maintained, as shown in Figure 3. The variation in the contact arc a during abrasively removing is controlled by the ratio of the rate of feed of the wheel to the rate of traversal of the wheel; for a constant traversal rate, increasing the feed rate increases the variation of the contact arc a.

Preferred embodiments of the present invention seek to solve these and other problems.

Accordingly, in a first aspect the present invention provides a method of abrasively removing material from a workpiece, the method comprising the steps of rotating an abrasive wheel about a first axis and orbiting the wheel about a second axis spaced from the first axis to contact said workpiece with a circumferential surface of the wheel to remove material therefrom.

Preferably the first axis and the second axis are substantially parallel.

Preferably, the distance between the second axis and the workpiece is decreased with each orbit of the wheel.

In a second aspect the present invention provides a method of abrasively removing material from a workpiece comprising rotating an abrasive wheel about a first axis, orbiting the wheel about a second axis parallel to the first axis and advancing the wheel and/or workpiece towards each other in a direction perpendicular to the first axis.

The method may further comprise effecting relative traversing motion of the wheel and workpiece.

Preferably, the wheel orbits the second axis at least once, the depth of the cut made in the workpiece by the wheel increasing with each orbit.

The second axis may be moved continuously towards said workpiece. Alternatively, the second axis may be moved towards said workpiece when the wheel is not removing material therefrom.

In further aspects the present invention provides apparatus suitable for use in the methods set forth above.

Preferred features of the present invention will now be described, purely by way of example only, with reference to the accompanying drawings in which:-

Figure 1 is a schematic diagram showing an abrasive sectioning wheel entering material during sectioning thereof;

Figure 2 is a schematic diagram showing an abrasive sectioning wheel traversing material during a cut;

Figure 3 is a schematic diagram showing an abrasive sectioning wheel

traversing material during a cut whilst the wheel is fed into the material;

Figure 4 is a schematic diagram showing the motion of the abrasive sectioning wheel of the apparatus for abrasively removing material according to the present invention;

Figure 5 is a schematic diagram showing the incremental increase in the depth of a cut produced in a method of abrasively removing material according to a preferred embodiment of the present invention.

According to the present invention, an abrasive sectioning wheel 30 rotates in a conventional manner about a first axis 32 passing through the centre thereof. In addition, the wheel orbits about a second axis 34 spaced from the first axis. Such eccentric motion of the wheel is shown in Figure 4. The angular velocity of the rotation of the wheel about the first axis is greater than that of the orbit of the wheel about the second axis 34.

The second axis 34 is parallel to the first axis 32. The area swept out by the wheel 30 as it orbits about the second axis 34 is coplanar to the rotational plane of the wheel 30 about the first axis 32.

Material is removed from the workpiece, 36 as the wheel 30 orbits the second axis 34 to contact the circumferential surface of the wheel with the workpiece. This surface may be profiled to produce a rectangular, V-shaped or similar cut in the workpiece 36.

In order to increase the depth of the cut, the distance between the second axis and the workpiece 36 is decreased as the wheel orbits the second axis. Bringing the second axis closer to the workpiece may be effected by movement of either the second axis 34, the workpiece 36, or both.

Such motion may be performed continuously or may take place whilst the

wheel is not removing material from the workpiece. In either event, no time is wasted in bringing the second axis and the workpiece closer together as this motion occurs during the orbit of the wheel 30 about the second axis 34.

With reference to Figure 4, with no feed of the wheel 30 the wheel orbits about the second axis so that the first axis moves in a clockwise manner between points A, B, C, D. Of course, the wheel 30 may orbit in an anticlockwise manner. As shown in Figure 4, the wheel 30 contacts the workpiece 36 to create the cut 38 during the movement of the wheel between position A to position C via position B.

For the majority of an orbit of the wheel about the second axis 34, the wheel is not in contact with the workpiece 36. Therefore, when the wheel 30 is fed continuously towards the workpiece 36, the percentage of the total feed of the wheel during a single orbit occurring whilst the wheel is in contact with the workpiece is low. As a result, the variation in the contact arc *a* is low.

The shape of the base of the cut 38, or the "profile" of the cut 38, is dependent upon the position of the workpiece 36 relative to the direction of the feed of the wheel 30, the distance between the first axis 32 and the second axis 34 and the rate of feed of the wheel.

With no feed of the wheel, as shown in Figure 4, the distance D_y measured along axis y between the second axis and the base of the cut 38 as the cut progresses between position 40 and position 42 increases initially from position 40 to position 44 and then decreases from position 44 to position 42.

With continuous feed of the wheel 30 towards the workpiece 36, the distance D_y comprises two components, a first component varying as described above and a second component dependent upon the motion of the second axis 34 during cutting. With constant motion of the second axis 34 along axis y towards the workpiece 36 during cutting, this second component of D_y

increases continuously as the cut 38 progresses from position 40 to position 42.

The rate of feed of the wheel towards the workpiece is chosen preferably so that the second component of D_y is substantially less than the first component of D_y.

In a preferred embodiment of the present invention shown in Figure 5, the cut is formed in the workpiece 52 during rotation of the first axis 32 between points A and B only.

As shown in Figure 5, the shape of the base 56 of the cut formed in the first orbit of the wheel about the second axis is substantially reproduced as the depth of the cut increases with subsequent orbits of the wheel. This is the case with either no feed of the wheel whilst the wheel is in contact with the workpiece or with continuous feed of the wheel.

For example, in increasing the depth of the cut from position 56 to position 58, a rises rapidly as the wheel enters the workpiece at the start of the abrasively removing. It reaches a maximum value a_{max} which is substantially maintained for the majority of the abrasively removing until the wheel begins to exit the side 54 of the workpiece 52. a then decreases as the wheel leaves the material.

With no feed of the wheel whilst the wheel is in contact with the workpiece, a_{max} is dependant on the distance that the wheel is advanced towards the material during the period of orbital rotation between points B and A. Similarly, with continuous constant feed of the wheel, a_{max} is dependent, for a constant rate of rotation of the wheel about the second axis 34, upon the rate of feed of the wheel.

The depth of the cut increases with further orbits of the wheel about the second axis. As shown in Figure 5, the depth of the cut at position 66 is such that by one further orbit of the wheel about the second axis the workpiece would be sectioned.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

CLAIMS

1. A method of abrasively removing material from a workpiece, the method comprising the steps of rotating an abrasive wheel about a first axis and orbiting the wheel about a second axis spaced from the first axis to contact said workpiece with a circumferential surface of the wheel to remove material therefrom.

2. A method according to Claim 1, wherein the distance between the second axis and the workpiece is decreased with each orbit of the wheel.

3. A method of abrasively removing material from a workpiece comprising rotating an abrasive wheel about a first axis, orbiting the wheel about a second axis parallel to the first axis and advancing the wheel and/or workpiece towards each other in a direction perpendicular to the first axis.

4. A method according to Claim 3, comprising effecting relative traversing motion of the wheel and workpiece.

5. A method according to any preceding claim, wherein the wheel orbits the second axis at least once, the depth of the cut made in the workpiece by the wheel increasing with each orbit.

6. A method according to any of Claims 2 to 5, wherein said second axis is moved continuously towards said workpiece.

7. A method according to any of Claims 2 to 5, wherein said second axis is moved towards said workpiece when the wheel is not removing material therefrom.

8. Apparatus for abrasively removing material from a workpiece, said apparatus comprising an abrasive wheel having an abrasive circumferential surface and rotatable about a first axis passing through the centre thereof, said wheel being mounted to orbit about a second axis spaced from said first axis.

9. Apparatus according to Claim 8, wherein said first axis and said second axis are substantially parallel.

10. Apparatus according to Claim 8 or Claim 9, further comprising means for advancing the wheel and/or workpiece towards each other in a direction perpendicular to the first axis.

11. Apparatus for abrasively removing material from a workpiece, said apparatus comprising an abrasive wheel mounted for rotation about a first axis, means for orbiting the wheel about a second axis parallel to the first axis and means for advancing the wheel and/or the workpiece towards each other in a direction perpendicular to the first axis.

12. Apparatus according to Claim 10 or Claim 11, comprising means for continuously moving said second axis towards said workpiece.

13. Apparatus according to Claim 10 or Claim 11, comprising means for moving said second axis towards said workpiece when said wheel is not removing material therefrom.

14. A method of abrasively removing material from a workpiece substantially as herein described with reference to Figure 4 or Figure 5 of the accompanying drawings.

15. Apparatus for abrasively removing material from a workpiece substantially as herein described with reference to and as shown in Figure 4 or Figure 5 of the accompanying drawings.

Fig.1.

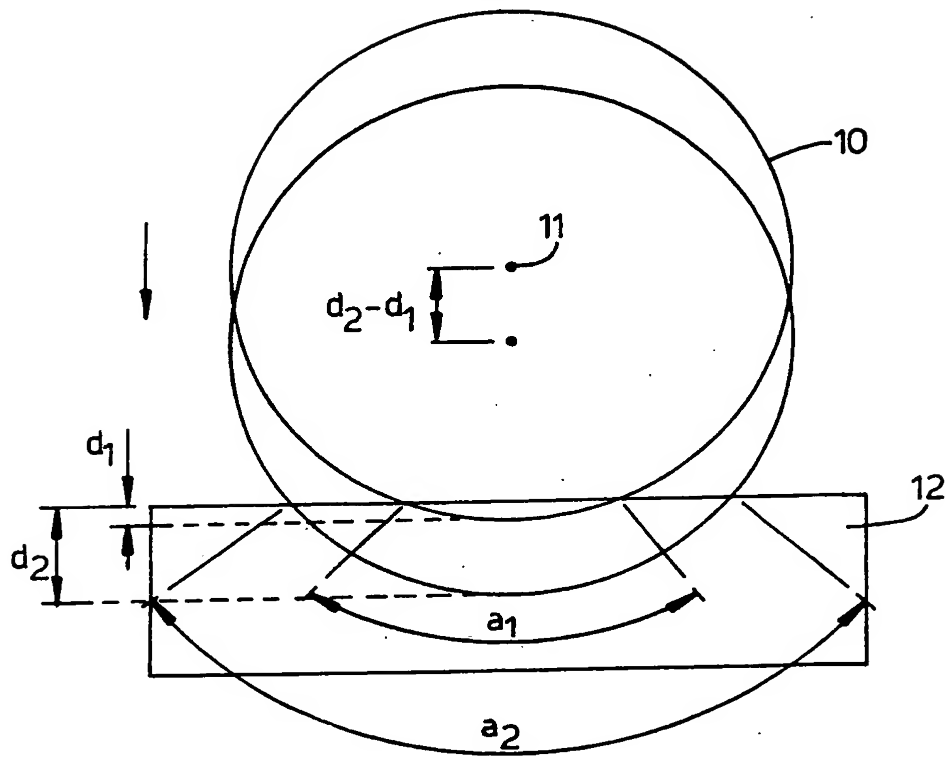

Fig.2.

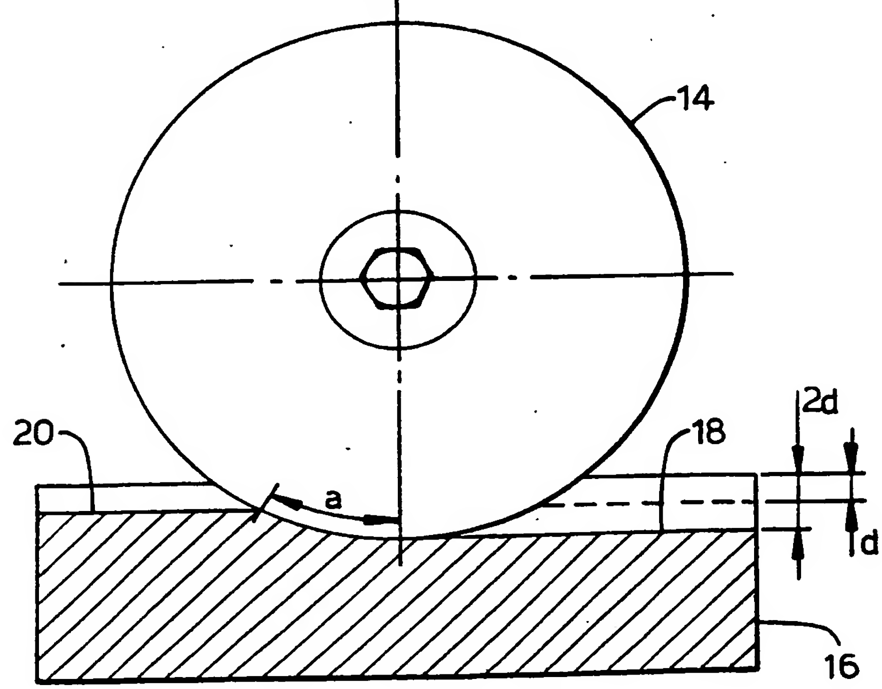

Fig.3.

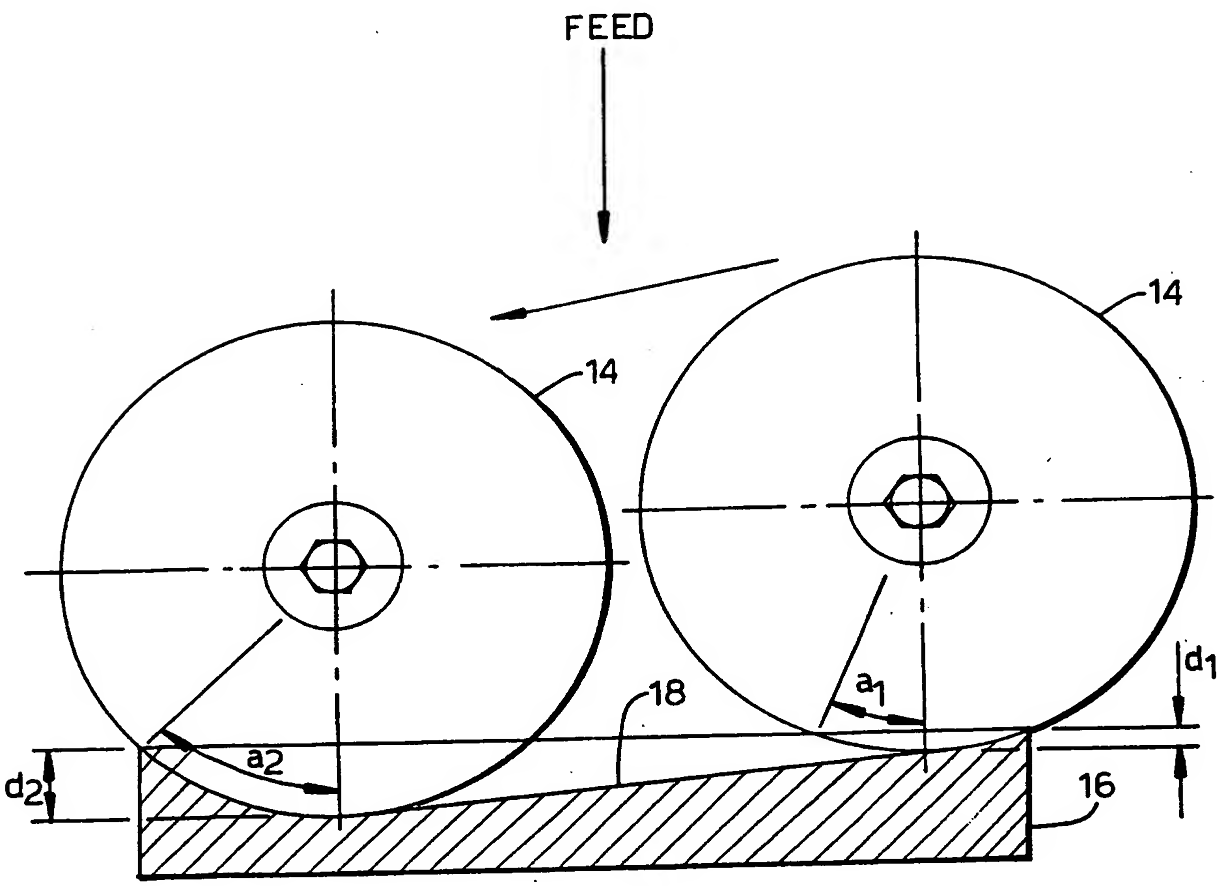

Fig.4.

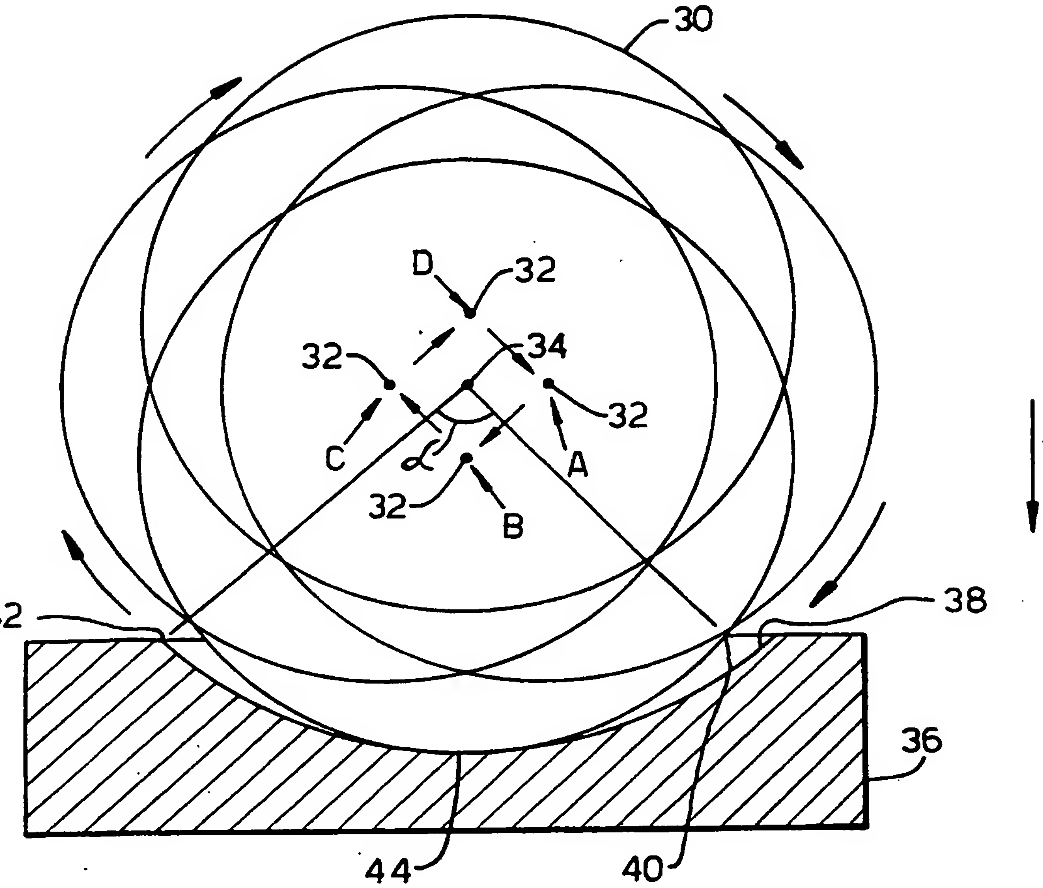
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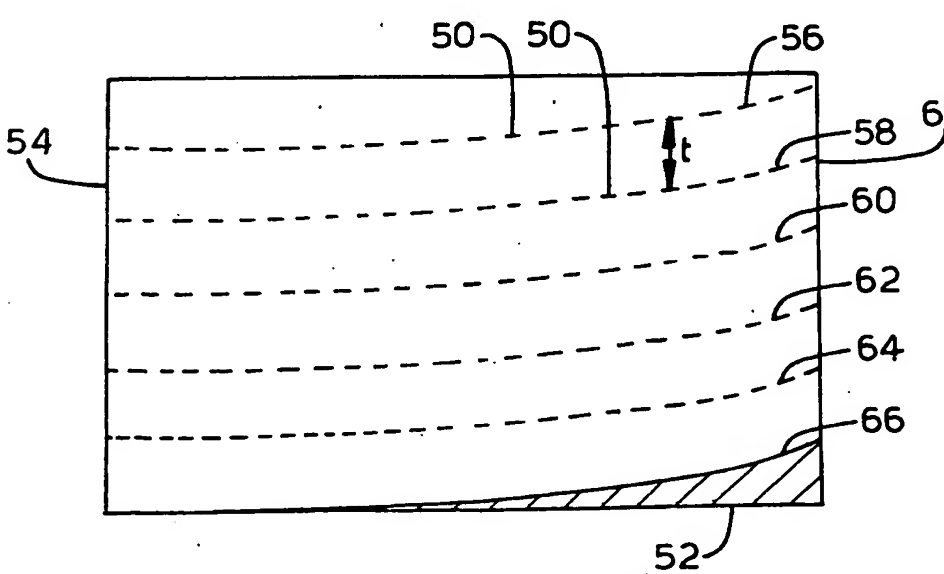
Fig.5.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INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24B27/06 B23D47/12 B23Q5/04 B24B1/00 B24B47/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24B B23D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 23 947 B (LEWIS JOHN HOWELL BALLINGER) 6 February 1958 see column 4, line 63 - column 5, line 32; figures ---	1,3,4,8, 9,11,14, 15
A	US 4 365 530 A (JOHNSON JR NOLTON C ET AL) 28 December 1982 see column 1, line 45 - line 53 -----	1,3,8, 11,14,15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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US 4365530 A	28-12-82	NONE	